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Technology indicators and developing countries

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UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Technology indicators and developing countries

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PREFACE

This report has been prepared pursuant to resolution 32 (VII) of the Committee on Transfer of Technology whereby the UNCTAD secretariat was requested, "drawing on the work carried out by other international organizations, to prepare a list of internationally comparable technological indicators in wide use, including methodology and explanatory notes". The study has been prepared with the assistance of Dr. Bernadette Madeuf-Michalet.

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Chapter I

INTRODUCTION

1. There is growing concern among policy-makers and academics about the role of technology in trade and development. The rapid pace of technological change has stimulated a renewed interest in technology issues, and efforts have been undertaken to develop indicators which permit an assessment of countries' scientific and technological capacities and the monitoring and evaluation of related progress and performances.

2. For more than 25 years now, there have been continuing efforts by both national administrations and international organizations to produce new and improve existing technology indicators. From the Frascati Manual by OECD, which provides guidelines for collecting and presenting data on resources devoted to research activities, to recent discussions on how statistical instruments could be adapted to measure the interrelationship between science, technology and economic performance, the interest has concentrated mainly in the more technologically advanced countries.

3. For developing countries, UNESCO has taken the lead in collecting information on scientific activities and human resource development. A number of other international organizations collect, on a regular basis, information which is of relevance for the construction of technology indicators (WIPO on patent activities; UNIDO on industrial statistics; IMF on balance of payments; World Bank on social development indicators; UNSO on trade statistics). 1/ However, this information is collected for other purposes and its value and usefulness for technological activities have not yet been appraised.

4. The absence of an integrated information system on technology-relevant information on developing countries is a serious constraint for constructing and applying technology indicators. Besides data limitations, the construction of technology indicators for developing countries is complicated by conceptual deficiencies as it is not clear whether or to which extent indicators as developed and applied in OECD countries are adequate for developing countries.

5. Developing countries vary greatly in their experience of industrialization and the usefulness of established technology indicators may also vary according to the levels of development or industrialization policies. There is little empirical evidence that would shed some light on these issues. Discussions on the role of technology in developing countries have been mostly confined to the firm level, with emphasis on the newly industrialized countries, and there is no coherent approach to assess the role of technology at the macro level. 2/

6. This report attempts to remedy this deficiency by providing an interpretation of technology indicators in terms of issues relevant to developing countries. The focus is on internationally comparable indicators which can be constructed on the basis of internationally published data sources. At country or industry level, more specific indicators could be constructed as the actual level of development and policy strategies, as well as different data sources, could be taken into account. However, there is a need first to provide a more general framework of technology indicators which may serve as a reference for further elaboration.

Chapter II

THE ANALYTICAL FRAMEWORK

A. The nature of technology and technological change

7. The presentation and discussion of technology indicators needs to be based on a understanding of the meaning of "technology" and "technological change". In recent years, numerous empirical and theoretical studies have contributed to a better understanding of technological change, thus challenging traditional views on technology. 3/ The predominant focus of these contributions has been on technologically leader countries. Although this does not invalidate the conceptual understanding of technological change in general, it leaves open many questions concerning the importance of technology features specific to developing countries.

8. Technology, broadly defined as the application of knowledge to produce goods and services, involves the dynamic interaction of human skills, physical assets, and organizational and institutional settings. This very broad definition calls for a more detailed explanation to highlight some important features of technology. Technology is not a form of "information", that has the properties of being costly to produce but virtually costless to transfer and use. On the contrary, technological knowledge is often tacit (i.e. cannot be codified in the form of instructions) and is mostly specific to firms and to particular products and processes. Technology involves a fundamental learning aspect, characterized (Nelson and Winter (1982)) by varying degrees of opportunity, appropriability and cumulativeness.

9. Opportunity stems from the scope of technical opportunities and the easiness with which technological advance can be achieved for a given effort. Appropriability relates to the capability of firms to internalize economic benefits, which in turn is influenced by learning curves, lead times and industrial property protection. Cumulativeness refers to the mostly incremental advance of the knowledge base.

10. Technological change as a process does not correspond to the formerly accepted linear model wherein scientific knowledge gives rise to technical innovation. This "science push" model was relying on assumptions relative to the scientific sourcing of techniques and the existence of successive and distinguishable phases from science to industrial applications. On the other hand, the "demand-pull" model is not accepted either. In this model the rate and direction of innovations were determined by economic activity, and more specifically by the demand for capital goods. It is now recognized that the process of technological change includes complex interdependencies among the various stages of innovative activity where the supply of technology and the demand for technology are interrelated. Moreover, there are considerable variations among sectors, products and technologies in the rate, direction, and determinants of technological change.

B. Implications for measurement

11. The general features of technology and technological change outlined above have important implications for the measurement and interpretation of technology indicators.

12. First, indicators measure only aspects of technology rather than particular bodies of knowledge. Thus, they may reflect elements of science and technology, such as human resources, physical assets, organizational settings or the economic and legal environment, but they do not cover the entire constellation of the elements which constitute technology. Accordingly, there is no unique or superior indicator. Each has its strengths and weaknesses and for the purpose of analysis a range of indicators needs to be adopted.

13. Secondly, the cumulative and firm-specific character of technological change implies that technological strengths of firms and countries do not change rapidly over time. This means that technological patterns and trends in the recent past are a reliable guide to events in the not too distant future. It also means that some comparisons of levels and composition of "technological accumulation" across regions and countries (Patel and Pavit (1988)) are possible.

14. Thirdly, while easy to specify in principle, each indicator involves many thorny research issues. For example, what operational definitions should be used for counting scientists and engineers? Should it be by their formal degrees, their current work activity? Or, in what sense do patents reflect rates of technical innovation?

15. Fourth, due to the complex and multidimensional interactions between the different elements of technology, it is difficult to trace causalities among technology indicators. Moreover, in view of the dynamic nature of technological change, the relative importance of technology indicators varies not only across industries and countries but also over time. Thus, technological change is not synonymous with physical capital accumulation, or scientific advances, even if it overlaps with both of them.

16. Fifth, additional data constraints in developing countries, regarding availability and quality of technology-relevant information suggest the consideration of an even broader range of technology indicators than those used for developed countries.

17. Sixth, the relative importance of individual indicators and their interpretation varies according to the level of development and differences in economic policies of countries. Technical assistance, for example, is a major source of technology for least developed countries while for higher income developing countries it is of little relevance. Similarly, a growing inflow of capital goods or foreign direct investment may be interpreted as increased availability of technology or as a growing dependency on foreign technology.

C. Classification of technology indicators

1. General criteria for classification

18. Different criteria can be applied for classifying technology indicators depending on the purpose and level of aggregation of the analysis.

19. One type of classification which takes into account the process-character of technological change distinguishes three broad categories of indicators: input indicators, which measure the resources devoted to the generation of scientific and technological knowledge; output indicators, which measure the

outcome of scientific and technological activities; and technology-related indicators of economic performance which are used for assessing the effect of technology on economic performance. This type of classification appears suitable for both technologically-advanced, as well as developing countries, because the basic features of the process are the same across countries, although different indicators may need to be used to take into account differences among countries in levels of development and industrialization policies.

20. Another set of criteria for classifying technology indicators aims at discerning basic components of technology in the form of (UN (1988)):

(i) Object-embodied technology;
(ii) Person-embodied technology;
(iii) Document-embodied technology;
(iv) Institution-embodied technology.

21. Interpreting technology as a combination of hardware and software is useful to better conceptualize various forms of technology. However, at the aggregate level it appears difficult to apply such criteria because, in most cases, it is impossible to separate hardware from software.

22. Other criteria, such as capital intensity, new or mature technology, industry of origin and end-use (e.g. electrical machinery, consumer durables) are very useful when indicators are designed for individual countries or when industry-specific analysis is carried out.

2. A framework of technology indicators

23. Indicators can be classified using several of the above criteria simultaneously. Because of its more general applicability, the classification which is based on the interpretation of technological change as a process is the main classification used in this report. Therefore technology indicators will be discussed under the following three major headings: (a) input indicators; (b) output indicators; (c) technology-related economic performance indicators.

24. Input indicators can be further distinguished according to the source of the technology.

(a) Imported or transferred technology such as foreign direct investment, imports of capital goods, payments for proprietary technology and technical assistance; and,

(b) Domestic inputs or "efforts", such as resources devoted to science and technology, human resource development and investment in plant and machinery.

25. A distinction between imported technology and domestic efforts is useful on several grounds. Imported technology constitutes a major source of technology for all countries, especially developing countries and as such it deserves to be treated separately. Moreover, by comparing imported technology with domestic efforts, important insights as regards their relative contributions to technological change can be obtained.

26. Regarding indicators of the generation of technology, or "output indicators", it will be shown that the range of indicators, in general, and for developing countries, in particular, is limited due to the overall weak interrelation between science and technology, lack of data and conceptual constraints in defining inventions and innovations across countries.

Technology-related economic performance indicators can be divided into:

(a) Performance indicators related to the domestic economy, such as productivity changes and product innovation.

(b) Export or trade performance indicators, such as changes in market shares of technology intensive products and exports of technology.

27. A separation between domestic performance indicators and export performance indicators is considered, necessary on several grounds. First, it can be argued that domestic performance influences technological competitiveness and thus export performance. Therefore, there is a certain causality between these two types of performance indicators which necessitates a conceptual distinction. Secondly, the degree of countries' export orientation is strongly influenced by non-technology factors such as overall development policies, balance-of-payment conditions, etc., which suggest that domestic and export performance indicators measure different aspects of technological change.

28. Finally, another set of indicators which are often used to measure technological performance includes the level of industrialization and structural changes such as changes in the composition of GDP, the sectoral distribution of labour force and the composition of domestic output and trade. These "structural characteristics" are to a large extent the point in time outcome of technological changes and, hence characterize the level of technological development. Given the scope of this paper, structural characteristics are not considered explicitly.

29. In chapters III, IV and V, input, output and performance indicators are discussed as regards their measurement definitions, theoretical rationale and data availability in order to arrive at an assessment of each indicator's analytical strength. Since indicators are variables that represent an assumed relationship, the major focus is on the interpretation of the indicators.

Chapter III

TECHNOLOGY INPUT INDICATORS

30. Resources devoted to the generation of scientific and technological knowledge form the input side of the science and technology system. For developing countries, it is useful to adopt a broad definition of input elements which includes, in addition to R & D activities, transferred technology and domestic efforts in the form of human resource development and investment in plant and machinery.

A. Transferred technology

1. General

31. The meaning of imported or transferred technology is subject to different interpretations. "Technology transfer" implies that the recipient of technology not only acquires hardware and software but eventually accumulates the technical knowledge, which is necessary to master the imported technology. There is general agreement that countries need to develop specific capabilities in order to achieve this.

32. The international transfer of technology can take place under several forms whose relative importance varies from one country to another. They may involve both commercial and non-commercial flows. The former is mainly realized through the import of "technology-embodying" capital goods (either in the form of individual pieces of machinery and equipment or completely assembled turn-key plants), foreign direct investment, and the transfer of disembodied technology via the licensing of patents, know-how agreements, supply of technical and consultancy services, joint ventures, skilled labour migration, etc. Non-commercially transferred technology, on the other hand, includes, most notably, technical co-operation funded by official government agencies and by non-governmental organizations and customers, and information contained in professional journals and publications.

33. Attempts to quantify internationally transferred technology are faced with serious data constraints, particularly as regards contracts on proprietary technology, new forms of investment, employment of foreign skilled labour and the acquisition of codified information. Moreover, there is a high degree of overlapping among the different sub-categories of transferred technology, since a single transaction often includes more than one form of technology transfer. Foreign direct investment, for example, is frequently combined with licensing agreements between parent companies and affiliates (UNCTC (1987)) and may also involve trade in capital goods. These characteristics need to be considered when individual indicators are interpreted.

34. The selection of individual indicators of internationally transferred technology, which are discussed here, is determined by the availability of data and their statistical relevance for developing countries. They fall in the following categories:

(i) Imports of technology-embodying products;

(ii) Foreign direct investment;

(iii) Payments for proprietary technology; and,

(iv) Technical co-operation grants.

2. Imports of technology-embodying products

35. Imports of technology-embodying products is one of the most important forms of commercially transferred technology. Imports of machinery and equipment as derived from international trade statistics within section 7 of SITC 4/ constitute the most accurate and comprehensive statistical data for measuring such transfers. Several indicators can be constructed by combining or selecting subgroups of SITC 7.

(i) Imports of subgroups of SITC 7 ranked by degree of "technological intensity", (National Science Board (1989), OECD (1989), UNCTAD (1988)) where technology intensity is defined by the R & D intensity of industrial output, e.g. the following subgroups are "high-technology-intensive": aircraft and parts (7114, 734), office machines and computers (7141, 7147, 7143, 7149).

(ii) Imports of capital goods more generally. One possible approach (UNCTAD (1988)) is to exclude from SITC 7 consumer goods, such as domestic appliances (7194), television receivers (7241), radio and broadcast receivers (7250), passenger motor cars and chassis (7321 and 7326), motor cycles and bicycles (7329 and 7331).

36. Another measure of international transfer through technology - embodying products is the imports of specific products from other SITC sections which are considered as having a high-technology content and are used in production, for example, scientific measuring and controlling instruments (861) and optical and medical instruments (5419).

37. The methodology used for assigning products to different technology-intensity groupings has various shortcomings and as will be discussed in the next chapter has been criticized on several grounds.

38. Similarly arguments can be brought forward against using imports of individual products, which are assumed to embody a high degree of technology. This approach is useful when countries with homogeneous productive structure are the subject of the analysis. However, for cross-country comparisons, it is difficult to define such categories of products since technological needs and specialization vary among countries. Due to the difficulties in defining technology-intensity across countries with different industrial profiles, the imports of capital goods, as defined above, would appear to be a more useful measure of transferred technology for cross-country analysis.

39. A major disadvantage of capital goods or other broad definitions of technology-embodying products as an indicator of transferred technology is that little can be said about their technology content. This results from differences, among countries, in the composition of capital goods as well as in the vintage of goods within the same subgroup of imported capital goods. Thus, the share of farm machinery in total capital goods imports is likely to be higher in agro-industry based countries than in developing countries with a strong manufacturing base, and the vintage of e.g. electrical machinery between two developing countries might differ considerably.

40. In conclusion, imports of capital goods are a suitable indicator of the level of transferred technology. Their statistical significance and the availability and quality of data make it an important indicator for internationally transferred technology. The fact that little can be said about its technology content and the efficiency of the actual transfer limits the usefulness of the indicator as an explanatory variable of technological change.

3. Foreign direct investment (FDI)

41. Transnational corporations play an important role in the international transfer of technology. Among the different arrangements through which transnational corporations may transfer technology, FDI is, in value terms, the most important one. It is also the only one for which comprehensive statistical series are available. Other arrangements are (UNCTC (1987)) joint ventures, licensing, franchising, contractual arrangements on management, marketing and technical services, turn-key contracts and international subcontracting.

42. Foreign direct investment involves the financial flows associated with the establishment by a transnational corporation of an affiliate in a foreign country over which the parent firm is assumed to exercise effective control. It may involve either the acquisition of an existing enterprise or the establishment of a new enterprise. FDI is frequently combined with licensing agreements or other forms of contractual arrangements.

43. Data on foreign direct investment is collected by the IMF on the basis of the balance-of-payments statistics provided by countries. Its measurement however involves several problems which are sources of international discrepancies. There problems derive mainly from the following:

(i) level of foreign control of shares defining FDI;

(ii) treatment of reinvested earnings;

(iii) financial sourcing for the development of affiliates; and,

(iv) the sectoral breakdown of FDI.

44. The level of share control (or voting powers) above which an investment is defined as FDI ranges generally from 10 to 25 per cent. Despite the IMF definition and OECD efforts in providing a "benchmark definition", countries differ in their definitions of FDI. Thus, variations in national measurement of FDI may give rise to different values of the same flow of FDI according to whether it is measured by the country of origin or the recipient country.

45. Some countries consider reinvested earnings by affiliates of foreign enterprises as part of the direct investment flow, and they include them in their FDI statistics. Others - particularly developing countries - do not collect data on reinvested earnings. As a consequence, there are some differences between the national evaluations of the same FDI flows and stocks. Usually there is a large excess of net credits reported to the Fund, because debit entries (mainly by developing countries) are less complete than credit entries as compiled by large creditor countries (mainly developed countries).

46. Financial resources for the development of assets controlled by foreign enterprises do not consist only of the registered FDI flows - inwards or outwards flows - as reported in the balance of payments. Other resources are reinvested earnings by affiliates and fund raising on financial markets, either national or international. Therefore, data on reported flows cover only one part of increasing assets. This part becomes smaller with time as the affiliates develop their activities and become able to finance their further growth. One important consequence is that the internationalization of productive operations does not necessarily imply growing international flows of FDI. An indicator measuring stocks rather than flows could be used to tackle this difficulty. Unfortunately, this type of data is not collected in the same way as FDI flows. Accuracy, periodicity, and international comparability are even less guaranteed than in the case of flows.

47. Regarding the technology content of FDI and its relevance as a channel of technology transfer it appears difficult to arrive at generalizations, since a wide range of factors play a role, which vary across countries. The technology that is provided through FDI may include any or all of the following: capital goods; industrial property rights in the form of patents, trade marks and branch names; secret unpatented process know-how that is specific to the investing firm; and the investment of the firm's skills in organization, management and training. On the other hand FDI may not involve any transfer at all, as in the case of simple acquisition of existing firms.

48. To which extent know-how is actually transferred may depend on the transfer costs as viewed from the investor (Teece (1986)) and the economic environment and market characteristics of the host country, which influence the contribution of FDI in the formation of management and technical skills, marketing know-how as well as other spill-over effects by way of direct links with suppliers and customers as well as indirect ones through leaks to other firms of the host country.

4. Payments for proprietary technology

49. Probably the most direct form of technology transfer is through the transfer of disembodied technology. One way of measuring such transfer is by using the payments for proprietary technology e.g. licensing of patents, know-how agreements, management contracts. Information regarding such payments constitutes part of the payments for services in the current account balances under the item Technology Payments (TBP). Although this item, theoretically covers all transactions relating to trade in technical knowledge and services with a technology content, in practice, TBP includes a range of non-technology related flows while excluding some important ones. Furthermore, data is currently available only for OECD countries and, in most instances, it covers only royalties and licensing fees. Improvements in data quality and coverage should, however make TBP a meaningful indicator of international transfer of disembodied technology (OECD (1988), UNIDO (1989)). Hence, the need to include a discussion of the definition, measurement and interpretation of TBP in the present report.

50. Technological balances of payments are generally composed of two categories of payments: those corresponding to commercial transactions on elements protected by industrial and intellectual property rights and those implied by the supply of services with a technical content. Each category

includes largely heterogeneous flows with varying technological content. It is generally considered that technological balance of payments covers a wider range of payments than definitions of know-how would imply.

51. Conversely, there may be technology transfer without associated technological payments. In many instances payments do not appear in the technological balance of payments as they are hidden in other payments such as the profit remittances of transnational corporations. In so far as technology transfers constitute intra-firm flows, reported technological payments tend to depend on the firms' transfer-pricing policies, which tend to be dictated by global strategy considerations rather than by technology costs. 5/ Host countries' legislations on profits and remittances are crucial in transfer-price setting. Since countries' legislations differ significantly in this respect, the correspondance between technology transfers and payments as reported in TBP will vary significantly. This would tend to limit the international comparability of TBP since the same technology transfer in one country may be reported under TBP while in another under profit remittances or vice-versa.

52. Another limitation of TBP, derives from the fact that there is no internationally acceptable definition of which payments constitute trade in technology. The definition offered by the IMF Manual of Balance of Payments is not adequate because it does not make a distinction between the different types of contractual arrangements. Conversely OECD efforts to harmonize the collection and compilation of data are limited to OECD member countries (OECD (1988a)). However, some developing countries have been making efforts to improve their compilation of technological payments for many years. This is the case of countries implementing registration and/or screening systems of contracts implying technological payments (UNIDO (1989)).

53. The technological balance of payments covers a wider field than technological transfers. Besides commercial transactions on licences and know-how, transactions on trademarks, designs and models are also recorded. These different transactions are rather difficult to separate, and in many instances they are part of the same contractual arrangements combining trademark and industrial licences. Furthermore, there are other financial flows which do not correspond to industrial property elements and know-how but to intellectual property rights in general such as copyrights for art products.

54. A second category of technological payments is related to technical assistance taking place between enterprises on a commercial basis. These payments include various kinds of technical services with different technological content: consulting engineering studies, technical assistance, managerial and administrative services, or R & D performed abroad or funded from abroad. Some of these services are associated with technology transfer e.g. in form of licensing agreements.

55. Technology payments, by definition, would be a good indicator for measuring the transfer of know-how or technology not embodied in objects. However, the heterogeneous technology content of technology payments raises a series of questions concerning the interpretation of technology payments particularly when using it together with FDI. Moreover, the use of TBP for international comparisons is severely limited by the poor availability of data for developing countries.

5. Technical co-operation grants

56. Technical co-operation grants are an important form of non-commercially transferred technology. In particular, for less and least developed countries, they represent a major and often the only source of foreign technology. Technical co-operation grants cover the provision of resources by donor countries to developing countries with the primary objective to (a) augment the level of knowledge, skill, technical know-how or productive aptitudes or (b) to augment the capacity for more effective use of the existing endowment (OECD (1988b)).

57. Data on technical co-operation grants from individual donor countries and from multilateral agencies to individual developing countries is provided by OECD. The data concerns total grants only and therefore, it is not possible to identify the elements of technical co-operation grants such as training, fellowships, etc.

58. Overall, it is not possible to quantify at the cross country level the technology content of technical co-operation grants. The size of co-operation grants is influenced not only by technological requirements but also by political constraints and priorities. Moreover, investments in human capital formation involve long time-lags and this makes it difficult to assess the role of technical co-operation grants. Despite these limitations, it is indispensible to take this indicator into account, since for many developing countries technical co-operation constitutes a major inflow of technology. Its evolution over time and its distribution across countries are important features of developing countries' economic and technological strengths.

B. Domestic technological efforts

1. General

59. Domestic technological efforts in the form of R & D activities, human resource development, and physical investment are fundamental input elements for accelerating technological change. Their importance is two-fold. First, they are a necessary pre-condition for building up indigenous technological capabilities. Secondly, sustained domestic efforts are crucial for the effective utilization of imported technology.

60. The role of domestic technological efforts in influencing the level of technological mastery of imported technology is of particular importance and raises a series of interesting questions. Thus, a central question in interpreting and assessing imported technology and domestic efforts, at the macro level, relates to the balance between them and the dynamic interaction of their different elements.

61. The nature of domestic technological efforts and their impact on technological accumulation are influenced by a wide range of factors which include the physical and institutional infrastructure, financing systems, market characteristics and policies. Moreover, these factors influence the interactions between R & D activities, human resource development and physical investment. Data and conceptual constraints make it impossible to take these aspects into account in the construction of indicators. It is, therefore, necessary to discuss measures of R & D activities, human resource development

and physical investment separately. However, one has to be aware that they are strongly interdependent and that they are influenced by the techno-economic environment.

62. Finally, it is important to distinguish conceptually between domestic technological efforts as input elements into the process of technological change and as domestic technological capabilities. While the first is a dynamic concept, the second is the point in time outcome of technological change, reflecting progress achieved in the past.

2. Research and development (R & D) activities

63. R & D has become a widely accepted indicator of innovative activity. R & D indicators have attracted the attention of policy makers, since scientific knowledge is increasingly needed for the development and application of advanced technologies. National institutions and international organizations such as UNESCO and OECD have undertaken considerable efforts to make R & D statistics comprehensive and comparable.

64. According to UNESCO, research and experimental development is broadly defined as "any systematic and creative work undertaken in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this knowledge to devise new application". The resources devoted to research and experimental development are defined as the "core" of scientific and technological activities. Other science and technology indicators used by UNESCO are: "scientific and technological education and training broadly at the third level" and "scientific and technological services (STS) performed or financed by all national institutions in the fields of natural science, engineering and technology, medical and agricultural sciences as well as in the fields of social sciences and humanities".

65. Two broad categories of R & D indicators can be distinguished: R & D expenditures, which capture the financial resources, and human resources employed in R & D activities. The global figures give only a measure of the intensity of R & D activity. Additional information about the internal structure of R & D is, however, necessary when analysing the technological effort itself and for international comparisons. Gross Domestic Expenditure on Research and Development (GERD), as provided in national accounts, is the indicator used for R & D expenditures. The indicators describing the internal structure of R & D are obtained by disaggregating GERD using mainly the following criteria:

(i) Type of R & D activity - basic research, applied research, experimental development;

(ii) Sector of performance - productive sector, higher education, general services;

(iii) Branch of economic activity in the productive sector; and,

(iv) Source of funding: Public, private.

66. As regards human resources, the total number of scientists, engineers and technicians engaged in R & D, expressed in full time equivalent, is

disaggregated by field of study, sector of performance or branch of economic activity. For the purpose of international comparisons various standardized ratios are constructed, including:

(i) R & D expenditures as a share of economic resources (GNP);

(ii) R & D expenditures per capita;

(iii) R & D personnel as a share of total scientists or engineers; and,

(iv) R & D personnel per 10,000 employees in the corresponding sector.

67. Despite efforts by UNESCO in providing guidelines for definition and measurement techniques, developing country data on R & D activities are of only limited international comparability (see Teitel (1987)). The definition of scientists and engineers, for example, is not uniform across countries, the years for which data is available are not the same in each case and in some countries data on R & D expenditures is available only for the public sector. Besides data constraints which make time series analysis impossible, there are both general problems in interpreting R & D activities as well as problems specific to developing countries.

68. In general, R & D indicators measure only formal R & D and neglect two important sources of scientific input: production engineering departments in large firms and part-time innovative activities in small firms. As a result, R & D indicators tend to underestimate the volume of scientific input directed towards production technology and related capital goods (Patel and Pavitt (1988)). However, on the whole, measures of R & D activity can be used as indicators of domestic technology efforts but in developing countries need to be interpreted with caution because of the lack of uniformity in the quality of the data collected by UNESCO.

3. Human resource development

69. There is general agreement that human capital formation in the form of education and training is an essential ingredient for development. In this respect educational systems are of particular relevance since they shape to a large extent the levels of skills embodied in the workforce.

70. UNESCO provides definitions on educational systems and technical manpower and collects data on literacy, educational enrolment at the first, secondary and tertiary level as well as data on vocational training. Concerning data on, what UNESCO defines as, the "scientific and technical manpower potential", the information available is of a very general nature. The data covers the total numerical strength of the most qualified human resources, defined by either the total number of, or the number of economically active, persons who possess the necessary qualifications as scientists, engineers or technicians.

71. Based on the available information as provided by UNESCO, the following indicators are frequently used to assess the skill-potential of countries (see e.g. Lall (1990)):

(i) Adult literacy rates;

(ii) Enrolment in primary, secondary and tertiary education as a percentage of age groups;

(iii) Tertiary level students by technical fields (general science, natural sciences, engineering) as percentage of population;

(iv) Enrolment in vocational training as percentage of population or of employees in the manufacturing sector; and,

(v) Number of scientists, engineers and technicians per million population.

72. Once again, the coverage and quality of the data leave much to be desired. Definitions, for example, are not uniform across countries, the years for which data are available are not the same for all countries and for many countries the data are simply out of date. These data constraints are particularly severe for data on higher education, vocational training and number of scientists. Moreover, important firm-specific forms of training, such as on-the-job training, are not included. Another, and probably more important limitation results from the conventional classifications of levels of education. They fail to take into account that the degree and specialization of skills need to correspond with the actual industrial requirements, which in turn are determined by the types of applied or planned technologies.

73. Despite these general shortcomings, indicators of human resources are indispensible for assessing countries' technological input. There is general agreement about the link between levels of education and economic development (Dean (1984)). It is also beyond doubt that basic education is important for all production techniques, irrespective of their degree of sophistication. Accordingly, literacy rates do provide an indication of the overall quality of the workforce. Similarly, proportional shares of secondary and tertiary educational levels give valuable indication of the existing levels of higher skills and ratios of scientists and engineers of approximate levels and pools of more specialized skills.

4. Domestic investment in plant and machinery

74. The rate of investment determines the pace at which new processes, incorporating new technologies and/or leading to the manufacture of new products are incorporated into the country's capital stock and diffused through the economy. In this sense, domestic investment in plant and equipment can be considered as crucial to the realization of technological opportunities. However, an increase of physical capital and a corresponding output growth, alone, is not sufficient to accelerate technological change. In a dynamic setting, an increase in capacity needs to be accompanied by technological learning, increased process innovativeness and product improvements. Hence, domestic investment needs to be seen as a necessary but not sufficient condition for technological change.

75. Data on Gross Domestic Investment (GDI) for developing countries are collected by UNSO, the World Bank and regional commissions of the United Nations system. GDI is derived from national expenditure accounts and includes: all new equipment produced domestically or purchased from abroad as well as all imported second-hand goods; all new dwellings; expenditures on the

improvement of durable goods and non-reproducible tangible assets (such as land, mineral deposits, plantations); and additions to livestock herds. Commonly used indicators based on GDI are:

(i) Flows of GDI, its changes over time and its share in GNP as a measure of overall investment activity;

(ii) GDI per capita or per employee in the manufacturing sector as measures of investment intensity or capital intensity.

76. Capital goods constitute a very important vehicle of technologies used in the production process. In the same way as imports of capital goods are one form of acquisition of technology, production of capital goods represents a means of developing domestic technological capabilities. At the international level, data on production of capital goods is obtained from UNIDO's industrial production statistics tabulated according to the International Standard Industrial Classification (ISIC). Based on this data it is possible to construct estimates of domestic production of capital goods as a component of domestic investment. ISIC 381 to 385 is a widely used classification of capital goods (UNIDO (1985), UNIDO (1979)). This category includes metal products (381), non-electrical machinery (382), electrical machinery (383), transport equipment (384) and professional and scientific equipment (385). Major disadvantages with this data is the limited country coverage (about 35 major developing countries) and insufficient adjustments for exchange rate fluctuations and inflation.

77. On the basis of the same statistics, several flow and stock indicators and ratios can be constructed:

(i) Flows of domestic capital goods output or its share over total manufacturing output to measure the domestic investment in hardware embodying technology;

(ii) Depreciated stocks of domestic capital goods to estimate the installed productive capacity;

(iii) Stocks of domestic capital goods per employee in the manufacturing sector to approximate degrees of mechanization.

78. Domestic capital goods (production less exports) in combination with imported capital goods are by far a better indicator for changes in the productive capacity than GDI. The latter provides only an aggregate picture of investment activities. Furthermore, it contains an unknown though not unimportant component which does not correspond with investment in plant and equipment. By contrast, investment in capital goods measures the physical scope for productive activities. Changes in capital stocks indicate rates at which machinery is renewed and - implicitly - a country's potential to benefit from newer technology. Similarly, the level of domestic capital goods production reflects technological capabilities of countries. Leaving aside cyclical or demand related influences on the output of domestic capital goods, their volume and composition reflects technological capabilities accumulated in the past.

Chapter IV

TECHNOLOGY OUTPUT INDICATORS

79. There are as yet no direct measures of the "output" of technology. The only indicators used are based on data collected for other purposes. The most commonly used output indicators in OECD countries are based on patent activities and scientific publications. The use of these indicators for developing countries raises a series of complex questions, which result mainly from the different links between science and technology in these countries.

80. The use of patents as an output indicator of scientific and technological activities has been developed since the pioneering work of Scherer and Schmookler (1965). Improvements of data banks on patenting activities, in general, and of the United States Patent Office, in particular, have led to numerous studies on patent activities. 6/ Most of these studies have focused on OECD countries. For developing countries there is hardly any empirical evidence on the role of patents. The second output indicator, bibliometrics, constitutes a relatively controversial area of science and technology indicators. Initially it was science historians and scholars who found interest in bibliometrics since the early 1960s as a research tool in the history of science.

A. Patent activities

81. A patent can be defined as a statutory privilege granted by a Government to inventors for a fixed period of years, to exclude other persons from manufacturing, using or selling a patented product or process. The major function of patents is to encourage innovation by granting monopoly rights to industrial property right holders and to promote the general welfare by striking a balance between encouragement of creation, on the one hand, and diffusion of the creativity, on the other.

82. Patent data are collected by WIPO, whose membership numbers over 170 countries and territories. Patent data are classified according to IPC (International Patent Classification) which differs from both ISIC and SITC. The IPC classification is product based. It includes five sections: human necessities; performing operations and transport; chemistry and metallurgy; textiles and papers; and fixed construction and mechanical engineering. Four categories of patent indicators are frequently used:

(i) Applications filed (patents granted) in a country by (to) its nationals and residents;

(ii) Applications filed (patents granted) in a country by (to) non-residents;

(iii) Total applications or granted patents ((1) + (2));

(iv) Applications filed (patents granted) abroad by (to) residents of a country ("external patenting").

83. The use of domestic patent activities (i) to compare innovative activities across countries involves several problems. First, examination procedures and the ratio of granted patents to applications vary considerably

across countries. Secondly, the overall role of intellectual property systems depends on the technological development level and industrial development strategies. Thus, several developing countries have not yet, or have only recently, introduced effective patent laws. Thirdly, in developing countries, non-residents and multinational corporations account for the lion's share in filed patents. 7/ Accordingly, domestic patenting activities in developing countries are strongly influenced by multinational corporations, and this limits the usefulness of domestic patenting as an indicator of indigenous, innovative activities. Fourth, country differences in patent systems may also result from differences in industry specialization. The propensity to patent is strongly influenced by industry-specific characteristics, which determine the patentability of products or processes, i.e. the ease with which they can be imitated. Thus, patents have traditionally played an important role in chemistry and pharmaceuticals whereas in electronic consumer products or machine-building they are of relatively little relevance. Overall, the international comparability of domestic patenting activities is limited, particularly so for developing countries.

84. In order to neutralize country differences in patent systems, it is necessary to rely on external patenting. Here, indicators on patenting activities are mainly used to explain international differences in innovativeness with respect to trade. The superiority of external over domestic patenting as a technology output indicator has been empirically verified for OECD countries. 8/ Comparative analysis of external patenting in individual selected OECD markets has shown that external patenting in the United States is the best direct measure of international innovative performance (Soete (87)). The relatively better performance of the United States market as opposed to other OECD markets can be explained by its large size and importance as an export market. Various ratios and derived indicators have been constructed for more refined empirical analysis:

(i) To remove the country-size factor when technology input indicators and external patenting are compared, both are weighed by population;

(ii) To take into account the commodity composition of trade flows, Revealed Technology Advantage Indexes (RTA) are constructed. The RTA is exactly equivalent to the index of revealed comparative advantage used in trade analysis and compares a particular country's share of United States patenting within a sector, divided by that country's share in total United States patents. An RTA of over one shows a relative technological advantage;

(iii) In industrial analysis a country's exports in an industry is compared with the number of external patents; in this case both variables are normalized by population.

85. Although external patenting statistics appear to be a good output indicator in explaining differences in innovative activities among OECD countries, there are some drawbacks even for these countries which can be summarized as follows (Pavitt (85), Soete and Wyatt (82)):

(i) The propensity to patent in a certain export market is also influenced by the relative importance of that market;

(ii) International differences in patent classification systems hinder comparisons, particularly at the industry level;

(iii) Patenting activities vary considerably across industries and therefore generalized conclusions must be treated with caution. Thus, patents do not equally reflect innovativeness across industries but are largely a function of inter-sectoral differences in the relative efficiency of other barriers to imitation available to the innovator (e.g. secrecy, technical lags).

86. Although external patenting has proven to be a powerful indicator of innovative activities across OECD countries, its usefulness to explain developing countries' innovativeness is less obvious as the absolute number and share of developing countries' residents in external patenting is still very small. 9/ This makes it impossible to relate patent activities to industries or products. Even when only aggregate patent data (e.g. patents granted in the United States) by developing countries' residents are used, the numbers are too small to allow comparative analyses. Only for the most advanced developing countries are patent data of statistical importance.

87. In conclusion, patent activities of developing countries are only of limited usefulness in measuring technology output. Country-specific differences in examination procedures and industrial specialization as well as different emphasis of developing countries in using patent systems as a policy instrument to promote technological innovation render comparisons of domestic patenting activity difficult. Regarding external patenting, the small number, in absolute terms, of developing countries' applications for, or granted, patents in export markets hinder international comparisons.

B. Bibliometrics

88. Scientific publications (articles and books) and references are considered as a measure of the results of scientific and technological activities. Bibliometrics is the generic term used to describe data about publications. Compilation of scientific publications is not organized in every country on a systematic base and there is no international institution engaged in collecting and analysing data. A frequently used data-base is the Science Citation Index (SCI) created by the Institute for Scientific Information (ISI) of the United States (National Science Board (1989)).

89. The ISI selects, compiles and publishes bibliographies in every scientific field. It also maintains a data-base on scientific and technological publications and provides information services on scientific activities. The Science Citation Index includes publications in nine scientific fields (from clinical medicine to mathematics through physics and engineering technology). Within the main categories, publications are also classified in 106 specialities and according to the country of origin.

90. The original source used by ISI to build the SCI consists of a large group of influential journals (3,500 for the 1981 SCI corporate tapes of ISI). The original sources and the compilation procedures used raise different issues as regards both the international comparability of data within the data-base as well as its accuracy for measuring scientific

production outside the United States. Several factors suggest the need for caution in using bibliometric data as indicators of the result of science and technology activities in developing countries. First, the scientific journals used in the bibliographical indices, which serve as a basis for the construction of these indicators, do not include an adequate proportion of journals from developing countries (Teitel (1987)). Secondly, language is a barrier which tends to cause underestimation of the contribution of scientists in developing countries (Velho (1985)). Thirdly, and probably most importantly, science and engineering activities in developing countries are more concentrated in such activities as modification and incremental improvement which, while valuable in many respects, are not necessarily of publishable value. Finally, publishing facilities and access to the latest journals are more restricted in developing countries.

Chapter V

TECHNOLOGY-RELATED INDICATORS OF ECONOMIC PERFORMANCE

A. General

91. Although it is generally acknowledged that technological change is a fundamental determinant of economic growth 10/ and international competitiveness, 11/ it has proven notoriously difficult to design meaningful indicators which reflect the role of technology in economic performance. This has to do with the complex nature of technology and the dynamic interplay of numerous other factors which are difficult to isolate. Thus, the obvious relationship between technology inputs and domestic performance on the one side and domestic performance and competitiveness on the other side are difficult to grasp, for they are interdependent and the involved time lags are variable across industries and countries.

92. It is therefore not surprising that there is no single indicator that would adequately reflect technology-related economic performance. Instead, there are numerous indirect measures which fall into two broad categories:

(i) Indicators which are used to relate technological progress to domestic economic performance and

(ii) Indicators which attempt to capture the role of technology in trade performance.

93. Before discussing individual indicators, it is necessary to point out that their application and interpretation is often subject to underlying theories of trade and development. Given the scope of this paper, it is not possible to adequately cover these issues. Instead, only some important aspects are discussed, which help to interpret the technology dimension of the variables.

B. Productivity and technological change

1. General

94. The link between technological change and productivity can be best interpreted at the firm level. Here, productivity improvements can be associated with process innovation and product innovation. Process improvements, achieved e.g. by the introduction of new equipment, organizational changes and incremental learning, lead to productivity gains through improved cost efficiency and improvements of quality. The impact of product innovation on productivity is less clear. The introduction of new products or the improvement of existing products are reflected in productivity changes only to the extent that the cost-benefit relation between inputs and outputs improves accordingly. These firm level considerations are also valid at the aggregate national level although the interrelation is less clear due to variable time lags across firms and industries.

95. Many articles elucidate the methods of computation, their pitfalls, and difficulty of interpretation, particularly within the context of developing countries. 12/ One problem in measuring productivity in developing countries

is the relatively short time period for which the requisite data are available. Short time series may be unduly influenced by changing capacity utilization levels and cyclical variations. Changing levels of capacity utilization are particularly vexing, since it is often not clear whether they result from supply-side bottlenecks such as shortages of material or intermediates, from demand fluctuations or whether they reflect incremental learning. 13/

96. Among the productivity measures which are in wide use, one may distinguish between total factor productivity (TFP), which seeks to identify the sources of output growth and partial productivity ratios, where output changes are related to a single input, such as labour.

2. Total factor productivity (TFP)

97. TFP is technically defined as the ratio of the rate of growth of output and the weighted average of the rate of growth of inputs in terms of labour and capital. Thus, TFP changes are computed by subtracting from output changes the input changes, weighted by their cost shares. The share of the growth of output which cannot be explained by growth in labour and capital inputs is generally interpreted as "technical progress".

98. In TFP analysis, the focus may be either on the share of TFP growth over output growth or on in rate of growth of TFP. Although both approaches may be useful, there are cogent reasons for using the absolute rate of growth of TFP for inter-country comparisons. 14/ Even in the case of absolute rates of growth interpretation of inter-country or inter-industry differences is complicated by the effect of different initial levels of technological development and economic structures of the countries or industries concerned.

99. A further constraint in measuring and using TFP is the availability of reliable data. Industrial statistics on the sub-sectoral level are available for a limited number of countries only. Moreover, these data are often based on national currencies, and distorted by e.g. rapid inflation or protected markets. In order to arrive at internationally comparable data, considerable adjustments are necessary and a number of additional assumptions regarding currency conversions need to be introduced.

3. Partial productivity measures

100. The most familiar concept of productivity is that of partial productivity - for example, the average productivity of a single input, such as labour. This is generally measured by the value of output per unit of input. Depending on the level of aggregation, a variety of measures for labour and capital productivity are commonly used:

(i) Changes of GDP per capita;

(ii) Changes of manufacturing output or value-added per capita or per employee;

(iii) Investment as percentage of GDP divided by the growth rate of output, commonly referred to as Incremental Capital Output Ratio (ICOR) or "investment productivity" if its inverse is used;

(iv) Various refined capital productivity ratios where capital or output are disaggregated into e.g. imported and domestic components or output in specific sectors such as manufacturing.

101. In addition to the aforementioned problems of interpretation, which constrain all productivity measures, partial productivity measures suffer from the fact that they do not permit us to draw conclusions as to the relative contribution to productivity increase of the two factor inputs. Thus, an improvement in capital-output ratio may be due to improved labour productivity arising from changes in industrial organization rather than to superior investment efficiency of new capital. Similarly, labour productivity improvement may result from process innovations rather than from improvements in labour itself. A basic underlying problem is the substitutability between capital and labour which varies greatly among developing countries. Some of the issues involved are discussed in the following section on "factor intensity of trade".

102. Among the partial productivity ratios, it is value-added per employee, which appears to be the most suitable for approximating technological performance. As Hirsch (1974) has convincingly demonstrated, value-added per employee does not necessarily stand for capital intensity. Higher value-added of one country could be attributed to a more highly skilled labour force whose employment costs would be higher than those of a relatively unskilled labour force. Accordingly, value-added may relate to the contribution of both physical capital and human skills and is therefore a suitable aggregate indicator to approximate the effects of technological change.

C. Trade-related measures

1. General

103. Various trade-related measures also give indications of the competitive strength of countries and industries and can thus serve as indirect measures of technological performance. Exposure to international competition appears to be particularly suitable to identification of the technological strength of countries and industries as it makes it possible to relate a country's performance to average global performance and, implicitly, to the global dynamics of technological change. Technological change influences international competitiveness in at least two ways. First, the creation and introduction of new products is increasingly associated with a high technology content and it is these knowledge-based, high value-added and income-elastic products which capture a growing share of global trade. Secondly, the diffusion of innovations across industries also changes competitiveness in more traditional industries by altering costs of production. Accordingly, measures of trade performance which attempt to capture the role of technology reflect a country's ability to generate or adopt innovations and reveal its pace of technological advance relative to other countries. Commonly used technology-related trade preformance measures are:

(i) General measures of trade performance such as market shares or revealed comparative advantage;

(ii) The behaviour of trade in technology-intensive areas, based on:

factor intensity,
R & D intensity,
external patenting,
selected products such as capital goods;

(iii) Exports of technology:

embodied in foreign investment outflows,
receipts of technology payments.

2. General measures of trade performance

104. As in the construction of other types of measures of technology-related economic performance, absolute values must be transformed or normalized in order to arrive at analytically meaningful measures of trade performance. The different measures used for trade performance fall into three broad groups:

(i) Export performance measures, such as:

Growth of exports per capita or per employee,

Changes of market shares (a country's exports over world exports),

Changes of revealed comparative advantage (share of a good in a country's export relative to the good's share in world exports: RCA),

Constant market share analysis (CMS);

(ii) Trade balance measures, such as:

Changes of trade balances of goods (exports - imports),

Changes of normalized trade balances (exports minus imports over exports plus imports);

(iii) Trade orientation of production measures such as:

Export orientation (exports as a share of production),
Import penetration (imports as a share of consumption),
Self-sufficiency (production as a share of consumption).

105. The question of choice of performance indicators depends on the purpose of the analysis. Generally, export based measures are preferred because they permit stronger inferences about a country's technological competitiveness than do trade balance or trade orientation measures. The inclusion of imports and production in the latter two types of measure introduces more strongly the effect of domestic economy policies and demand variations which tend to distort imports more than exports (Balassa (1977)).

106. Among the export performance measures, technical and data as well as analytical strength for deriving policy implications differ considerably.

Normalized growth rates (per capita, per employee) and market shares make it possible to neutralize the effect of global growth of trade in the corresponding product category or industry. The RCA builds on this approach and includes the commodity composition. Depending on the level of disaggregation, relative strengths and weaknesses of individual countries' export composition can be thus identified. The CMS technique goes one step further. The decomposition of export growth into commodity, market-distribution and competitiveness effects, makes it possible to analyse and isolate the relative importance of geographical concentration on export performance. The need for exercising caution in interpretation of RCA and CMS, on both theoretical and empirical grounds, is extensively argued in the literature. The usefulness of the RCA and CMS for interpreting the influence of technology aspects is limited unless further assumptions are made. For example, linking RCA with product cycle theory allows identification and analysis of sequences of industries in which relative efficiency is likely to grow. Similarly, regression analysis based on assumptions derived from trade theories can be used to reduce further the unexplained competitiveness residual of the CMS.

107. However, reliance on export-based measures alone has its disadvantages. First, re-exports are not isolated although the use of value-added would help to circumvent this shortcoming. Secondly, intra-firm trade, which is difficult to correct for and which may have little to do with the host country's competitiveness, distorts the picture. Thirdly, the focus on exports masks a country's ability to fulfil its own market requirements. This aspect is of relevance if countries induce export expansion by policy measures that discriminate against the domestic market.

3. Technology intensity of trade

108. Various approaches attempt to define and structure the commodity composition of trade according to criteria of technological intensity. By comparing countries' performances with a technology-intensity scale of trade, conclusions can be drawn on their relative abilities to upgrade comparative advantage towards more knowledge- and skill-intensive industries. Each approach has its specific area of application and conclusions on countries' technological performance are tied with numerous underlying assumptions. Among the commonly used approaches those built on factor-intensity and of R & D intensity of trade are briefly reviewed below.

(a) Factor intensity of trade

109. One of the "stylized facts" of industrial development is that, with rising income and an increase in the stock of human capital, the pattern of specialization shifts towards higher value-added and capital-intensive industries. Accordingly, a country's relative technological performance is often analysed by examining the changing factor intensity of its trade. Various approaches have been used. 15/

110. Most typically trade statistics are grouped according to the following measures of capital and labour intensity:

(i) Gross fixed investment per employee;

(ii) Stock of capital goods per employee;

(iii) Value-added less wages over number of employees;

(iv) Wages per employee.

111. Relating trade performance to indicators of capital and labour intensity permits conclusions to be drawn as to the nature of countries' comparative advantage, and is a useful complement to more strictly technology indicators.

(b) R & D intensity of trade

112. The classification of industry and product groups according to the importance of R & D expenditures is one of the most common approaches used to define the technological intensity of output and trade. A country's ability to excel in high R & D-intensive industries or product categories can be viewed as an indication of its competitiveness in industries with high growth potential.

113. R & D intensity is measured by the ratio of R & D expenditure to production. This ratio is calculated for each industry at a given level of disaggregation. 16/ The different industries are then ranked from high to low and their R & D intensity is compared to the average R & D intensity of industrial output. 17/ Industries with R & D intensity above this average are defined as "technology intensive". Alternatively, several levels of "technology intensity" can be defined by grouping together industries with similar levels of R & D intensity, as shown in table 1 where the ratio of R & D expenditure to production for several industries is shown for 18/ OECD countries. The R & D intensity of trade products or product groups is the same as the R & D intensity of the corresponding industrial output.

114. The concept of R & D intensity has been widely used. 19/ Its major drawbacks are that the definition of the R & D classifications is highly sensitive to the year that is used as a benchmark and country coverage. 20/ (Soete (1987)). They also ignore the intra-industry diffusion of innovations (Palda (1986) and Hughes (1988)). The latter point is of particular importance to developing countries since, for technological followers, diffusion of innovations is often more important than the generation of innovations. The diffusion of innovation across industries is, however, not necessarily related to the R & D efforts of the industry where the innovation is generated.

115. A further complication arises from the dispersion of production processes across national boundaries. The low-skilled, labour-intensive part of producing a more or less complex final good is often shifted from the advanced industrialized countries to low-wage countries. Typically, this relocation is carried out by multinational corporations. Since the production of the intermediate parts usually falls in the same industry category as the final good, low-wage countries may appear to have a relatively large share of high-tech products in their total exports. In general, this reflects not these countries' capacity to produce high-tech products sui generis but rather the fact that they have a comparative advantage as a locus of production.

Table 1

Ranking of R & D intensities for 1980

		R a/
High		
1. Aerospace		22.7
2. Office machines, computers		17.5
3. Electronics & components		10.4
4. Drugs		8.7
5. Instruments		4.8
6. Electrical machinery		4.4
	Average	11.4
Medium		
7. Automobiles		2.7
8. Chemicals		2.3
9. Other manufacturing industries		1.8
10. Non-electrical machinery		1.6
11. Rubber, plastics		1.2
12. Non-ferrous metals		1.0
	Average	1.7
Low		
13. Stone, clay, glass		0.9
14. Food, beverages, tobacco		0.8
15. Shipbuilding		0.6
16. Petrol refineries		0.6
17. Ferrous metals		0.6
18. Fabricated metal products		0.4
19. Paper, printing		0.3
20. Wood, cork, furniture		0.3
21. Textiles, footwear, leather		0.2
	Average	0.5

Source: OECD (1986)

a/ R: Ratio of R & D expenditure to production.

(c) Trade performance in selected product groups

116. Another way of measuring technology intensity in trade is by focusing on specific products which are generally viewed as "new technology", "advanced technology", "core technology" or "strategic technology". Such terms are usually associated with products or activities to which a combination of characteristics can be attributed such as: the need for a strong

R & D effort; high growth potential; rapid product and process obsolescence; high-risk and large capital investment; high degree of international co-operation; competition in R & D and marketing; and high skill-intensity.

117. On the basis of the assumption that the current global industrial transformation is driven mainly by electronics-based innovations, it would appear justifiable to define e.g. the share or growth of trade in electronics products as an indicator of technological performance. The question of which electronics products to choose raises several questions and it appears difficult to establish a global definition. Differences across countries regarding industrialization strategies, areas of specialization and intra-industry differences as regards the generation and diffusion of electronics products suggest that internationally comparable standards are difficult to design. Such approaches appear to be more powerful in industry-level analysis, where specialized data is available that makes it possible to take into account diffusion patterns and degree of application.

118. A third approach to defining technology-intensive products is through definitions of capital goods (see discussion on imported technology) or engineering products. Since such products are a form of embodied technology, it appears justifiable to associate technological performance in exports with a country's ability to successfully export capital goods. By applying general trade performance measures, countries' technological performance can be analysed by e.g.:

Rate of growth of capital goods in exports.
Trade balances in capital goods.
Share of capital goods in total manufactured exports.

119. Since capital or engineering goods are of strategic importance to all countries' productive capacities, the interpretation of these indicators has fewer drawbacks than the narrower definitions of technology intensity, for example the indicators based on specific high-technology products. Nevertheless, their interpretation is not free of biases. Structural differences among developing countries and different export specializations suggest the need for caution in interpreting export performance in capital goods.

4. Export of technology services

120. Data on exports of technology services are valuable indicators of the technological strength of countries. Such services typically include technical know-how, technical and management services, and "embodied skills", such as technological dissemination associated with project exports.

121. In practice, such services are a component of investment abroad and overseas construction, licensing and technical agreements and an array of other commercial tie-ups such as joint ventures in e.g. research or marketing. As has been discussed in the section on technology imports, there are serious conceptual problems in identifying the technology content of foreign direct investment and secondary data on other forms of disembodied technology flows are not available.

Chapter VI

SUMMARY AND CONCLUSION

122. Despite the importance attached to the role of technology in trade and development, work on empirically validated technology indicators relevant to developing countries has been seriously neglected. This report seeks to fill this gap. On the basis of internationally published and comparable data an extensive review has been carried out, identifying and assessing the usefulness and applicability of science and technology indicators for developing countries. The review shows that there exists a wide range of indicators that can be used in making international comparisons. Each indicator has its own strengths and weaknesses, and any international comparison should use a range of indicators adapted to its purpose.

123. For the purpose of classifying technology indicators it is useful to adopt a broad definition of technology and to distinguish between technology input, technology output and technology-related performance indicators. For all countries, but particularly for developing countries, it is useful to divide further measures of technology inputs into imported technology and domestic technological efforts. Indicators of imported technology are constructed from statistics on capital goods imports, foreign direct investment, technical co-operation grants and on the more direct acquisition of technology in the form of licences and know-how agreements. Domestic technological efforts fall into three broad categories of human capital formation, R & D activities and investment in equipment. Indicators of technology generation or output are based on patent statistics (domestic and external registrations) and bibliometrics. Indicators of the economic impact of technological change refer either to the domestic economy or to foreign trade. Various measures of productivity are used to estimate the domestic economic impact of technological change. The influence of technological factors is also reflected in the structure and composition of a country's output and exports. Technology-related trade performance can to a certain extent be examined through techniques of revealed comparative advantage and analysis of market shares, through commodity classifications according to R & D intensities and external patent activities, and through an analysis of technology exports, chiefly in the form of capital goods and receipts for technology payments.

124. The usefulness of the indicators discussed in this report depends largely on the availability and quality of data, although problems of interpretation also need to be taken into account. In general, it is the input side which can be best quantified and assessed. Thus, for example, the role of transferred technology and its composition relative to domestic technological efforts can be analysed with relative ease, whereas less can be inferred from the available statistical data about the process of technological change itself. We may only assume that scientific and technological inputs drive the pace and direction of technological change. What can be measured and interpreted, however, is the outcome of the process of technological change, in which these inputs have been used.

125. The discussion on the indicators on imported or transferred technology showed that the availability of internationally applicable data as well as the technology content of the indicators varies considerably. For international

comparisons it is, therefore, necessary to apply the widest possible range of indicators. The statistically most reliable and most important indicators, in value terms, can be derived from trade statistics. Thus, indicators on capital goods imports provide a good picture on the quantitative aspects of the acquisition of embodied technology. Statistics on foreign direct investment and technical co-operation grants provide indispensable indications on transferred technology. However, it is difficult to measure their technology content and their interpretation requires taking into consideration country and industry-specific characteristics. Lack of data and measurement difficulties limit severely the usefulness of measures of direct transfers of technology.

126. Turning to domestic technological efforts, output of capital goods would appear a suitable indicator for measuring the domestic component of investment in equipment. Data constraints are particularly severe regarding the measurement of human capital formation and R & D activities.

127. The technology output indicators considered, i.e. patent activities and bibliometrics, were found to be of limited usefulness in measuring the outcome of scientific and technological efforts in developing countries. The major reason for this is that such indicators are designed to measure advances relative to the world scientific and technological frontier. Even when external patenting is used, the small number of external patents granted to developing countries does not allow international comparisons. Therefore, these indicators are of relevance for only a small number of relatively advanced developing countries.

128. Among the technology-related economic performance indicators of relevance to the domestic economy, productivity measures would appear to be the most suitable for analysing the outcome of technological change. The close link between process improvements, which is a central feature of technological upgrading, and productivity changes makes the latter a suitable indicator for measuring the pace and direction of technological change. The choice of productivity indicators is largely determined by the availability of data. Due to the scarcity of industrial statistics it is difficult to take advantage of the analytical superiority of TFP over partial productivity measures. Among the partial productivity measures, value-added per employee would appear the most useful aggregate because it includes the effects of both human and physical capital.

129. There is a wide range of indicators which can be used for the assessment of the technology-related performance of exports. However, the specific features of each indicator must be taken into account when examining and interpreting the empirical evidence. Thus, for example, concepts based on R & D intensity or patent intensity do not provide an overall account of technological performance in exports. They fail to take into account technological upgrading in non-science based industries or product innovation in industries where patent protection plays a minor role.

130. Similarly, factor intensities of trade need to consider the underlying assumptions concerning the substitutability of capital and labour. Ratios and shares in capital goods exports have the fewest limitations and, in view of their important role for technological development, they would appear as suitable general indicators of technology-related performance in exports.

131. Overall, internationally available data makes it possible to construct a wide range of indicators which permit analysis of certain aspects of the role of technology in trade and development. In areas where the existing indicators appear to be weak particularly as regards developing countries, efforts for improving quality, consistency and coverage of data by the agencies collecting the relevant data could be reinforced. Efforts should also go into the construction of indicators measuring aspects of technological change which are specific to developing countries as was seen in the various parts of the present report.

Notes

1/ For relevant statistical yearbooks see annex II.

2/ For firm studies see e.g. Katz (1987) for Latin America; Fransman (1984), Dahlman (1987) and Enos and Park (1987) for Asian countries; and Lall (1990), for semi- or nearly industrialized countries.

3/ For recent contributions see Freeman (1982), Rosenberg (1987), Dosi et al. (1988).

4/ Standard International Trade Statistics. Which are considered as having high technology content. Data is provided by UNSO, GATT, OECD.

5/ It has been argued that the higher the FDI flows the more difficult it becomes to interpret TBP, since in this case, the share of intra-firm flows in total TBP tends also to be higher. Madeuf (1984).

6/ See e.g. Patel and Pavitt (1988), Pavitt (1982, 1985), Saviotti and Metcalve (1984), Soete and Wyatt (1983), Soete (1987), Basberg (1987).

7/ Local residents account for only 25 per cent of filed patents in developing countries between 1973 and 1987 (WIPO statistics).

8/ External patenting of a country should include all the patents granted to its nationals and residents abroad. Since, however, a patent application may be filed in more than one country aggregating over countries would involve considerable double counting. It is therefore, customary to look at the foreign patents by the country of origin of the applicant or patent holder in single markets.

9/ The share of patents granted to developing countries' residents in the total number of patents granted in the United States over the period 1983 to 1988 was only 1 1/4 per cent (based on data from United States Patent and Trademark Office. See Annex 1).

10/ The role of technological change in contributing to economic growth has been empirically demonstrated within the framework of growth accounting. Thus, Solow (1957) has shown that during the first half of this century in the United States about seven eighths of total output increase was related to technical change. Further works confirmed the importance of technical change and tried to decompose the residual (Denison (1962)).

11/ Since Leontief's (1953) provocative findings there have been numerous contributions which have led to a gradual relaxation of Hekscher and Ohlin's original assumption. Instead of explaining trade composition on the basis of homogeneous labour and capital endowments, increasing emphasis has been put on technology variables. Thus, the technology-gap model (Posner (1961)) and the product cycle theory (Hirsch (1965) and Vernon (1966)) as well as subsequent refinements attempt to take into account international differences in the generation, diffusion and adaptation of innovations. Despite these efforts, it has proven difficult to empirically demonstrate the role of technology in trade at the aggregate level.

12/ For a review see Nelson (1981) and Grillichs (1988) and for particular problems within developing countries see Fagerberg (1981) and Chenery (1986).

13/ Enos and Park (1987) have shown how technological learning in Korean industries is reflected in levels of capacity utilization and productivity changes.

14/ As Pack (1988) argues, initially low input ratios might lead to unwarranted conclusions on the importance of technical progress even if the economy achieves a growth of TFP which exceeds that of the change in world best practice.

15/ See Balassa (1977) for a review and Syraquin/Urata (1986) for refined methods of estimating elasticities of capital and labour.

16/ For example, the level of aggregation used by OECD is that of the international surveys on personnel and expenditure devoted to R & D. OECD (1986).

17/ The average or total R & D intensity of industrial output is defined also by the same ratio but is usually obtained as the average of the individual industry R & D intensities weighted by each industry's share in total industrial output.

18/ The R & D intensity of the different industries has been calculated for 11 reference countries taken together as an area. OECD (1986).

19/ See e.g. Kelly (1977), Walker (1979), OECD (1986), UNCTAD (1987).

20/ Industries which are at the boundary of a group may move to another category depending on the year used as a benchmark.

Annex I

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Annex II

International Statistical Yearbooks

ILO, Yearbook of Labour Statistics

IMF, Balance-of-Payments Statistics

OECD, Geographical Distribution of Financial Flows to Developing Countries
Main Science and Technology Indicators

United Nations, International Trade Statistics Yearbook

United Nations, Yearbook of Industrial Statistics

UNCTAD, Handbook of International Trade and Development Statistics

UNESCO, Statistical Yearbook

United States (United States Patent and Trademark Office), Patenting Trends in the United States - State Country Report 1963-1987

WIPO, Industrial Property Statistics

World Bank, World Development Report

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